Interactive comment on "Latitudinal distribution of Trichodesmium spp. and N2 fixation in the Atlantic Ocean" by A. Fernández et al.
Anonymous Referee #2
Received and published: 11 August 2010

We thank this reviewer for his/her comments, which have helped us to improve our manuscript.

Fernandez et al. present a latitudinal distribution of the diazotroph Trichodesmium and N2 fixation during two cruises in the N. Atlantic. Their cruises are during Nov.- Dec., 2007 and Apr.-May, Oct 2008. They show that the highest abundances of Trichodesmium and N2 fixation rates are between 5 S and 15 N during both cruises, with much less in the S. Atlantic gyre. These rates and distributions are then correlated to aerosol optical depth (AOD) and subsequently iron input. Finally, they scale their rate measurements up to admittedly conservative total N. Atlantic N2 fixation rates of ≈ 6 TgN yr-1 and S. Atlantic rates equal to ≈1.2 TgN y-1.

Overall this is a well-written manuscript, and one I recommend for publication in Biogeosciences. I rank the scientific significance, scientific quality, and presentation quality as good. However, prior to publication I hope the authors can address a few items:

1. Please note your detection limits for the PO4 measurements. The text says that standard colorimetric methods were used and the detection limit of this technique approximates the presented N. Atlantic concentrations.

The lowest phosphate concentration detected in our study was 0.02 µM. We have added this information to the Methods section. The reviewer is right is pointing out that some of the very low concentrations measured in the North Atlantic approach the technique's limit of detection. In spite of this, the general latitudinal trend we describe, and its relationship with other variables measured, remain valid.

2. Please provide more detail regarding the AOD. Specifically, you use seasonal data. Is there data on a finer temporal resolution (8-day, or daily) just prior to each measurement? Is there a way to estimate deposition? Or residence times of dust derived Fe in the mixed layer (perhaps Croot et al. 2004 GRL could be helpful). My thought is that data on a finer temporal resolution may help explain why during 2008 Trichodesmium distributions were shifted south. Where was the ITCZ during the different cruises?

We did use AOD data at a finer temporal resolution, in particular at weekly and daily scales. However, spatial coverage of these data, as any other remote sensing product, gets poorer when the temporal scale is restricted. This means that when we used weekly and daily data, in many cases we were not able to obtain the AOD data for the particular location where we collected *Trichodesmium* samples. Our measurements of *Trichodesmium* are confined to a single longitudinal line, which means that our spatial coverage is relatively poor, and hence difficult to compare with high resolution AOD data. For this reason, we preferred to use seasonal data, which give a general idea of the latitudinal variability in atmospheric deposition. The ITCZ, which is associated with

increased precipitation and, presumably, enhanced wet atmospheric deposition, was located further north during the 2008 cruise than during the 2007 cruise. It is thus unlikely that this factor was responsible for the fact that *Trichodesmium* distribution extended further south during 2008.

3. A possible contributor to the further south distribution of Trichodesmium during the 2008 campaign is the B-V frequency over the upper 125m. Figure 3 shows the peak is broader and shifted south. Is this possible?

This is certainly possible. We have added a sentence to this effect at the end of section 4.1.

4. Please explain in a bit more detail the argument regarding vertical migration and water column stability on lines 20-23 page 2205. Wouldn't a less stable water column result in mixing of nutrients up or cells down and thus less energetic expenditure to migrate?

As it is well known, *Trichodesmium* is typically favoured by very stable conditions in the water column. Hence, the increased stability in the Equatorial region may have contributed to explain the increased abundance of *Trichodesmium*. As far as vertical migration is concerned, however, the point we wanted to make is that a shallower upper mixed layer is likely to reduce the energetic expenditure involved in vertical migration. Inadvertently, we mixed both arguments in the last sentence of that paragraph. We have now rewritten that sentence, which now refers solely to the role of the upper mixed layer depth.

5. Did you look at the integrity of cells that came through the ship's non-toxic water supply? Was there any type of physiological measurement that might indicate if the cells were stressed from the pump system (e.g. Fv/Fm comparison of trichomes collected using different methods?) Please note if information exists.

We regularly examined under the microscope samples collected both with the underway water supply and with Niskin bottles, and found that the filaments' shape and length were similar. We did not detect the presence of broken or damaged filaments in the samples from the continous water supply. Also, when crossing *Trichodesmium*-rich waters, we found intact colonies in the samples from the continuous water supply. The abundances we obtained for *Trichodesmium* filaments in the *Trichodesmium*-rich region between the Equator and 20ºN coincide with previous reports based on filament counts in samples collected with Niskin bottles (e.g. Tyrrell et al. 2004, Moore et al 2009). For all these reasons, we think that our sampling method for collecting *Trichodesmium* resulted in reliable estimates of *Trichodesmium* filament abundance.

It is indeed possible that *Trichodesmium* cells may have suffered physiological stress while passing through the pump system. Note, however, that N_2 fixation was measured in separate samples, collected with Niskin bottles in a CTD+rosette system. The samples from the continuous water supply were used only for abundance determinations.

6. In the last paragraph of section 3.4 the sentence. . . "There was a strong correlation between surface N2 fixation and euphotic layer integrated N2 fixation"

is expected. N2 fixation by Trichodesmium is light dependent and occurs in the surface of the ocean. I am not sure what this correlation adds? Please explain.

A strong correlation is to be expected only when *Trichodesmium* is the main N_2 fixer. If other (e.g. unicellular) diazotrophs dominate N_2 fixation, the correlation may be less strong because these organisms tend to have a more uniform vertical distribution. The fact that, overall, surface and vertically integrated N_2 fixation rates covary is important to implement models of N_2 fixation based on the remote sensing detection of *Trichodesmium*.

7. The 2nd paragraph of sec. 4.2 needs work. It seems to argue that phosphorus is not a control on N2 fixation because it is high in the South Atlantic but low in the North Atlantic. The low PO4 in the N. Atlantic is likely the consequence of the dust (Fe) stimulated diazotrophy. PO4 is likely high in the South Atlantic because Fe inputs are low. This is stated towards the end of the paragraph. However, I do not believe the statement that P availability is unimportant in controlling the large-scale distribution of N2 fixation in the Atlantic. PO4 was measured here and not P availability. The DOP pool is available to Trichodesmium and is drawn down in the North Atlantic relative to the South Atlantic. Clearly P is important for diazotrophy, though because of the DOP pool it is not limiting.

We do ackowledge the importance of P for N_2 fixation, and in this connection we cite the key studies of Sañudo-Wilhelmy et al. (2001) and Mills et al. (2004). What we wrote in this paragraph was specifically that P does not seem to play a role in controlling *the large-scale latitudinal variability* of N_2 fixation. It is true that the DOP pool provides P for *Trichodesmium* and other photoautotrophs, but the fact remains that P availability is lower in the North Atlantic, as evidenced for instance in the enhanced alkaline phosphatase activity (APA) measured there (Mather et al. 2008). APA is well known to increase in response to P limitation in phytoplankton. In spite of increased P limitation in the North Atlantic, as compared with the South Atlantic, N_2 fixation is higher in the North, which leads us to conclude that the large-scale latitudinal distribution of N_2 fixation in the Atlantic is not controlled by P availability.

8. Section 5, end of first paragraph presents a range of geochemical estimates for whole Atlantic N2 fixation. By whole Atlantic do you mean N. Atlantic? Isn't the Knapp et al. 2008 estimate a N. Atlantic study? Likewise, Hansell et al. 2007(?) have lower estimates than those presented here.

The study of Knapp et al. 2008 (their Table 1) does provide estimates for N_2 fixation in the whole Atlantic (35ºN-35ºS). The estimate of Hansell et al (2007), as published, refers only to the North Atlantic between 10ºN-35ºN. The range given by Knapp et al. (2008), which we cite in our manuscript, refers to the North and the South Atlantic together.

9. In the last paragraph of the paper you estimate contribution of N2 fixation to the total new N input in the N. Atlantic. This is likely an overestimate as the input of atmospheric anthropogenic N is relatively large. See review by Duce et al. 2008.

The reviewer is right in pointing out the importance of atmospheric deposition of N. We could not, however, include this flux in our calculations since we did not estimate it

during our study. We have introduced a sentence in this section to explain that the calculated contributions would be lower, particularly in the Equatorial region, if atmospheric deposition is taken into account.

10. Lastly, throughout the manuscript please write N2 fixation rates when speaking of measured rates and N2 fixation when speaking in general terms about the microbial process (i.e N2 fixation rates were highest between 5 S and 15 N not N2 fixation was highest between 5 S and 15 N)

We have introduced this change where appropriate.